Left posterolateral short atrioventricular Mahaim pathway connecting the left atrium to the left ventricular epicardium

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Introduction

Mahaim pathways are accessory pathways characterized by slow and decremental anterograde conduction and lack of retrograde conduction.[1,2] Most Mahaim pathways are right-sided with their atrial insertion at various sites along the tricuspid annulus. Left-sided Mahaim pathways are rare, and their electrophysiological and anatomical characteristics have not been well studied.[3–5] We report a case of atrioventricular reciprocating tachycardia (AVRT) using a left posterolateral short atrioventricular (AV) Mahaim pathway connecting the left atrium (LA) to the left ventricle (LV).

Case report

A 35-year-old female patient without structural heart disease was referred to our institution for catheter ablation of symptomatic paroxysmal tachycardia. At baseline, a 12-lead electrocardiogram showed sinus rhythm with no clear signs of ventricular pre-excitation. During burst stimulation and single extrastimulation from the right ventricle (RV), retrograde conduction with a decremental conduction property occurred, and the earliest atrial (A) potential was in the His bundle region. Atrial extrastimulation from the high right atrium revealed prolongation of the AH interval, shortening of the HV interval, and progressive pre-excitation with right bundle branch block pattern and the earliest ventricular (V) potential at 4 o'clock in the coronary sinus (CS) (Figure 1A and B). This anterograde conduction showed a decremental conduction property, suggesting the existence of a left posterolateral Mahaim pathway. Programmed pacing from the distal CS induced similar pre-excitation during both a drive train and extrastimulation (Figure 1C). A single atrial extrastimulation induced wide QRS complex tachycardia with right bundle branch block pattern and a cycle length of 342 ms. The morphology of the QRS complex and earliest V potential during the tachycardia were identical to those during maximum pre-excitation by atrial extrastimulation (Figure 2A and B). The atrial activation sequence during the tachycardia was identical to that during burst stimulation from the RV. A single extrastimulus from the RV reset the tachycardia, indicating ventricular involvement in the circuit. An overdrive pacing from the RV induced ventriculoatrial block, which resulted in termination of the tachycardia, suggesting the exclusion of atrial tachycardia. Atrial overdrive pacing could entrain the tachycardia with concealed entrainment, indicating atrial involvement in the circuit. From these findings, we determined the mechanism of this tachycardia to be antidromic AVRT using an anterograde Mahaim pathway and retrograde AV node conduction.

To identify the ventricular insertion site of the Mahaim pathway, activation maps in the LV were created during the tachycardia and constant atrial pacing from the CS using an Advisor HD Grid mapping catheter (Abbott, St. Paul, MN)

KEY TEACHING POINTS

- Left-sided Mahaim pathways are rare, and their electrophysiological and anatomical characteristics have not been well studied.
- Electrophysiological study revealed that the mechanism of the tachycardia was antidromic atrioventricular reciprocating tachycardia using a left-sided Mahaim pathway.
- Detailed mapping, including that inside the coronary sinus, revealed that the Mahaim pathway was considered as a short atrioventricular pathway connecting the left atrium to the left ventricular epicardium.

KEYWORDS Ablation; Atrioventricular reciprocating tachycardia; Coronary sinus; Left Mahaim pathway; Short atrioventricular pathway
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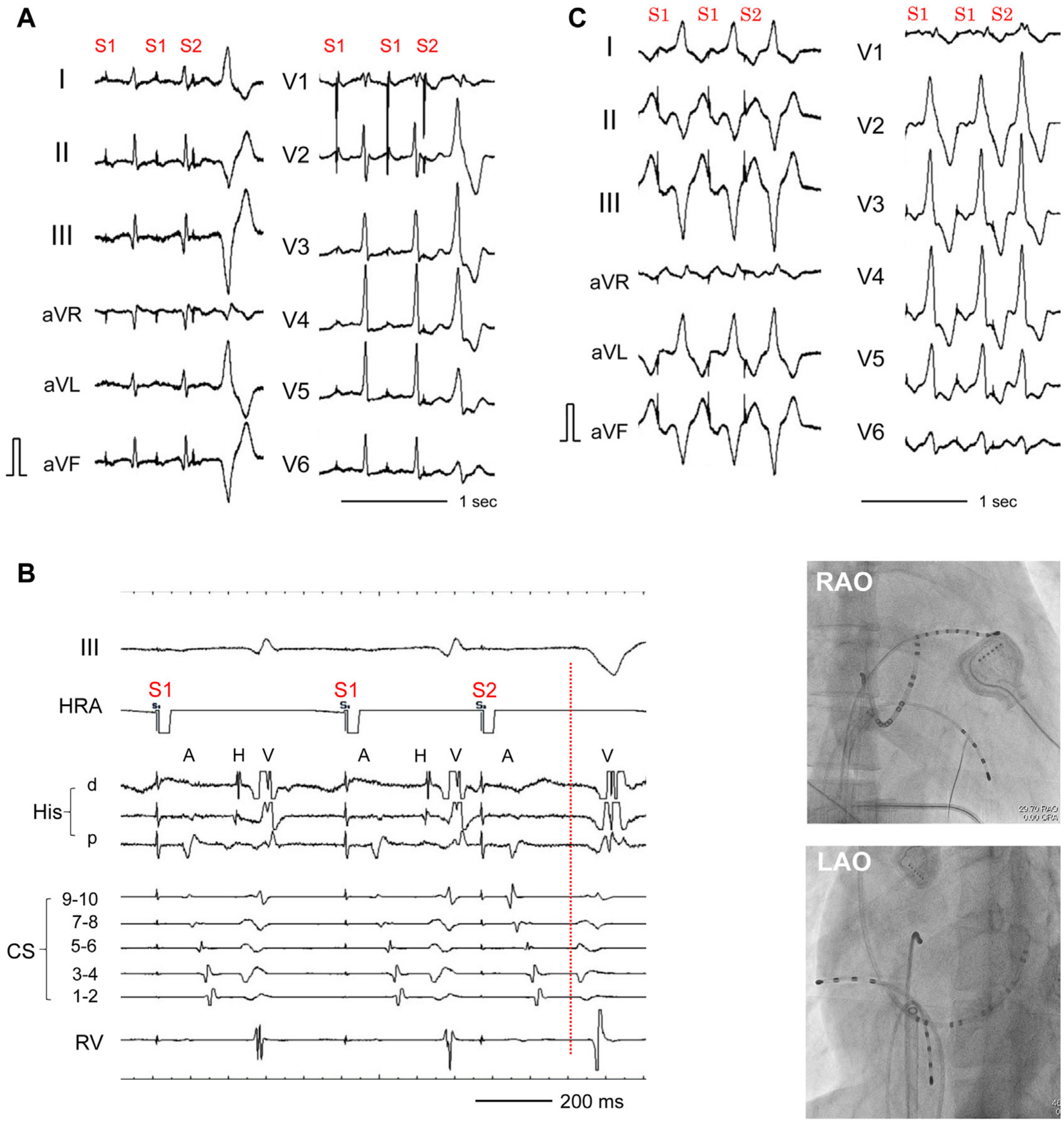

Figure 1 **A, B:** Twelve-lead electrocardiogram (**A**) and intracardiac recordings and catheter positions (**B**) during atrial extrastimulation from the high right atrium. The extrastimulation induced pre-excitation with right bundle branch block pattern and earliest V potential in the coronary sinus (CS 5-6). The His potential was lost in the V potential during the extrastimulation. **C:** Twelve-lead electrogram during atrial pacing from the distal CS showed similar pre-excitation during both basic and extrastimulation. A = atrium electrogram; d = distal; H = His bundle potential; HRA = high right atrium; LAO = left anterior oblique position; p = proximal; RAO = right anterior oblique position; RV = right ventricle; V = ventricular electrogram.

and EnSite Velocity 3-dimensional mapping system (Abbott). The earliest ventricular activation site was identified at the subannular site at 4 o'clock during both tachycardia and pacing from the CS (Figure 2C). The inside of the CS was mapped using a 3.5 mm irrigated-tip TactiCath ablation catheter (Abbott) during constant atrial pacing from the CS, also resulting in the earliest V potential being mapped at 4 o'clock inside the CS (Figure 2D). These findings suggested that the ventricular insertion site was the epicardial mitral annulus at the 4 o'clock position, and in fact, a dull potential suggestive of a Mahaim potential was recorded at this site immediately before the V potential (Figure 2D). To identify the atrial insertion site, the stimulus-to-QRS interval with atrial pacing was mapped with atrial pacing. The shortest interval was identified in the endocardial mitral annulus at 4 o'clock (Figure 3A). At this site, the Mahaim potential was recorded between the local A and V potentials during atrial pacing from the CS (Figure 3B), and radiofrequency (RF) application at a power setting of 35 W resulted in antegrade conduction block of the Mahaim pathway and disappearance of the pre-excitation (Figure 3C). The RF energy was applied for 40 seconds, and additional applications at the same setting were applied near the success site to consolidate the ablation lesion. No automatic rhythm was observed during the RF applications. No tachycardia could be induced by programmed atrial or ventricular stimulation. The patient has been free from palpitations during a 1-year follow-up period.

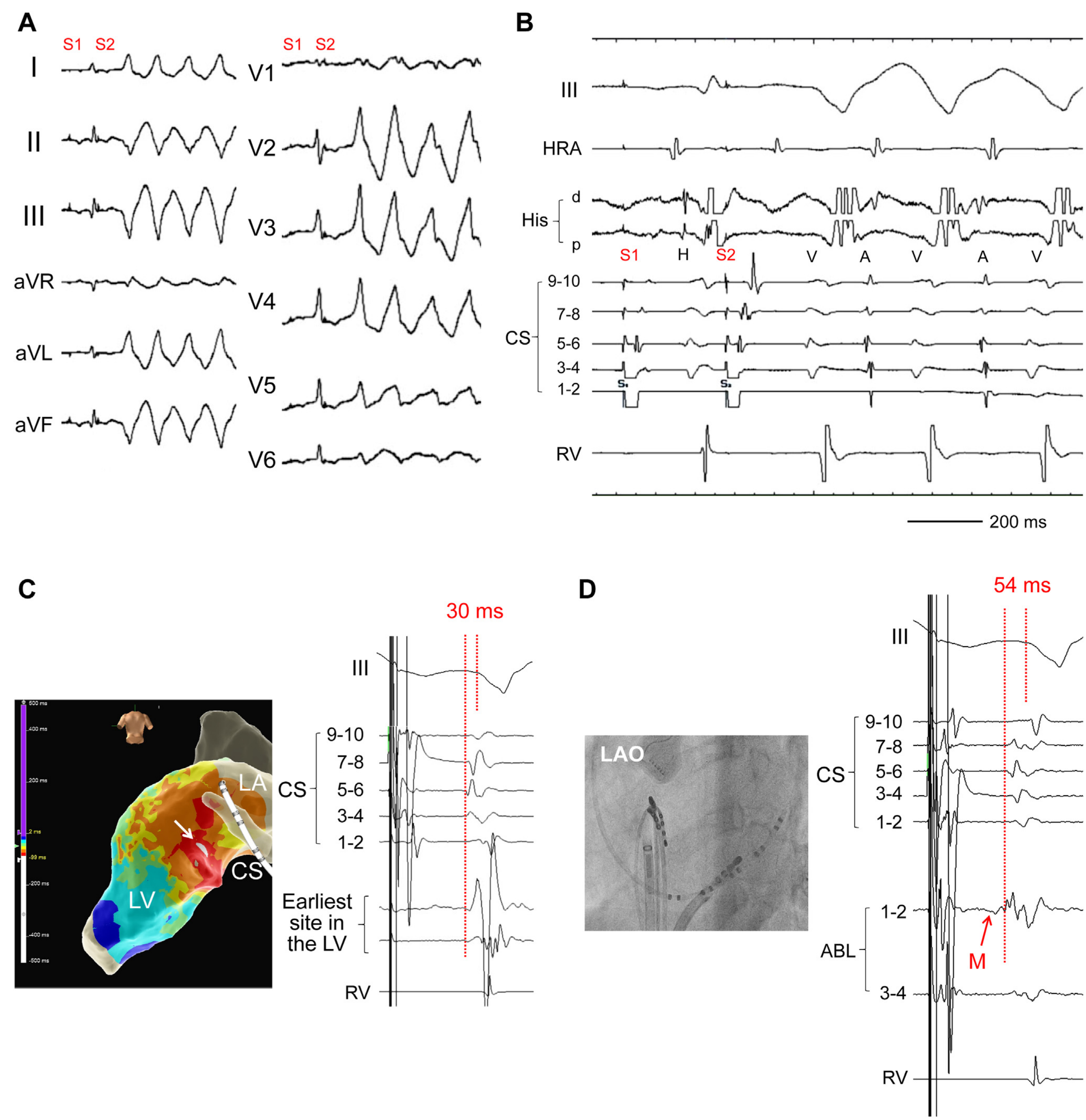

Figure 2 **A, B:** Twelve-lead electrocardiogram (**A**) and intracardiac recordings (**B**) at the initiation of tachycardia by atrial extrastimulation from the coronary sinus (CS). The QRS morphology and ventricular activation sequence were identical to those during maximum pre-excitation. The earliest atrial A potential was in the His bundle region. **C:** Activation map in the left ventricle (LV) during atrial pacing from the CS and intracardiac recordings at the earliest site in the LV. The earliest ventricular activation site was identified at the subannular site at 4 o'clock (*white arrow*). The V potential at the earliest site in the LV preceded QRS onset by 30 ms. **D:** Intracardiac recordings at the earliest site in the CS and the catheter positions. The V potential in the CS preceded QRS onset by 54 ms. A dull potential that was suggestive of a Mahaim potential was recorded immediately before the V potential (*red arrow*). ABL = ablation catheter; LA = left atrium; M = Mahaim potential. Other abbreviations are as in Figure 1.

Discussion

The accessory pathway in this case exhibited Mahaim-like features that include (1) an anterograde decremental conduction property, (2) no retrograde conduction, (3) lack of manifest pre-excitation at baseline, and (4) a prolonged AH interval and shortened HV interval, with manifestation of the delta wave during atrial pacing.[1,2,6] Mahaim pathways are now classified into at least 3 subtypes: (1) long AV accessory pathways that insert into the bundle branch (atriofascicular) or ventricular myocardium apart from the AV valve, (2) short AV accessory pathways that insert into perivalvular ventricular muscle, and (3) nodoventricular or

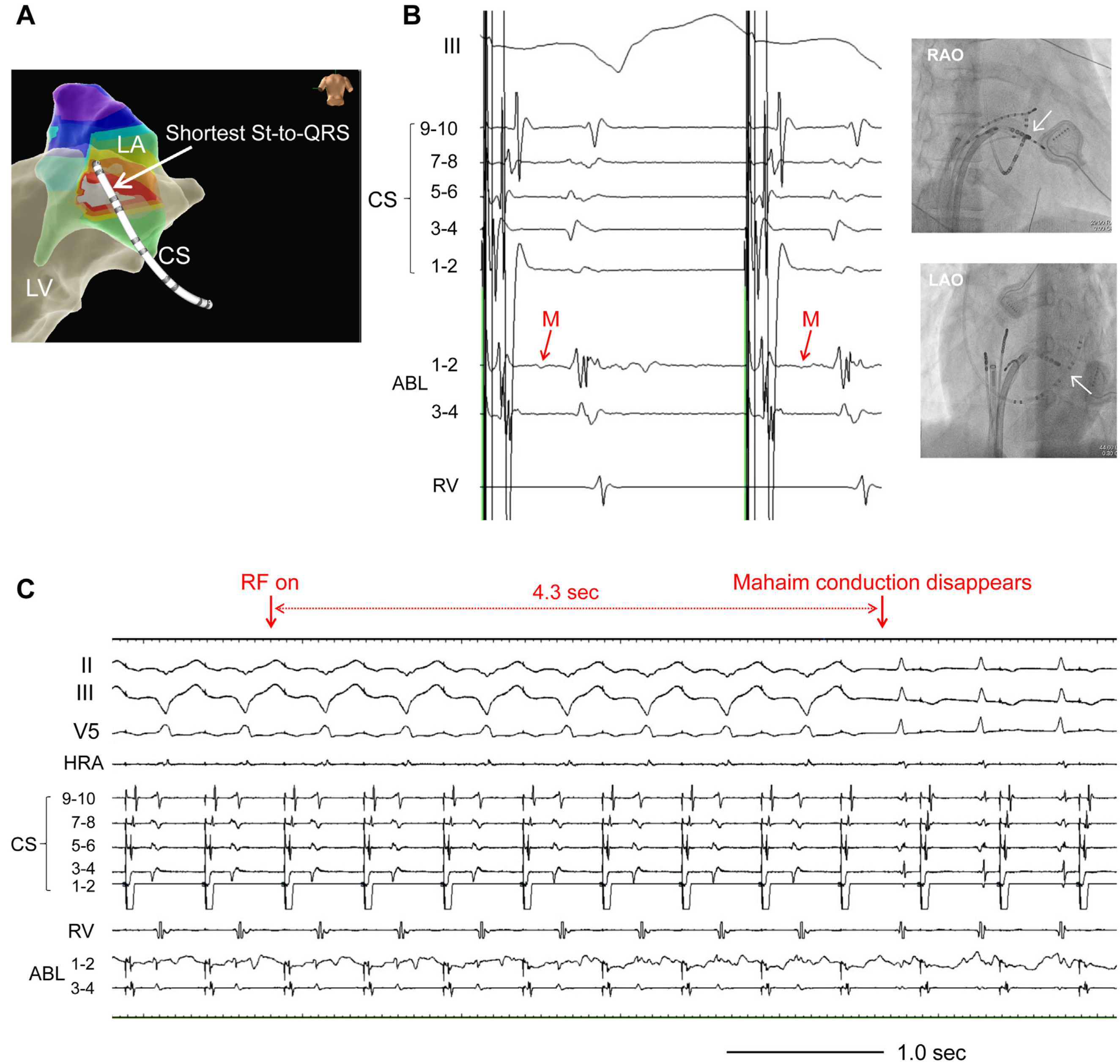

Figure 3 **A:** Three-dimensional image showing the site of shortest stimulus-to-QRS interval with atrial pacing (*white arrow*). **B:** Intracardiac recordings and catheter positions at the shortest stimulus-to-QRS interval. During atrial pacing from the coronary sinus (CS), a Mahaim potential (*red arrow*) was recorded between the local A and V potentials with the ablation catheter (*white arrows*). **C:** Intracardiac recordings immediately after radiofrequency (RF) delivery at the site where the Mahaim potential was recorded. The RF application at a power of 35 W was performed during atrial pacing from the CS. Antegrade conduction of the Mahaim pathway was blocked, and pre-excitation disappeared 4.3 seconds after the start of the RF application. Other abbreviations are as in Figures 1 and 2.

nodofascicular pathways that are linked to the AV node and usually emerge from the slow AV node pathways.[7,8] In the present case, pre-excitation was observed during constant atrial pacing from the distal CS but not observed during constant pacing at the same rate from the high right atrium, which suggested that the proximal insertion site was the LA and ruled out the nodoventricular or nodofascicular pathways. The atrial insertion was identified at the 4 o'clock position on the mitral annulus, and the ventricular insertion was considered to be the facing basal LV, suggesting that the pathway type was the short AV pathway. The earliest ventricular activation during atrial pacing from the CS was found inside the CS, indicating that the Mahaim pathway in the present case might have involved the neighboring CS musculature such as the left-sided Kent pathways.[5,9] The ablation strategy targeting Mahaim potentials has been reported to show favorable outcomes.[2] Therefore, we applied RF energy from the endocardial mitral annulus where the Mahaim potential was more clearly recorded than inside the CS.

In the embryological development process, the so-called "primary ring" that forms the AV node and the AV conduction axis contributes only to the tricuspid annulus. Most of atrial origins of the Mahaim pathway are presumed to derive from remnants of the specialized conduction tissue that shows an affinity to the AV node and is commonly found in the tricuspid vestibule. Therefore, Mahaim pathways including short AV pathways are often right-sided, and left-sided Mahaim pathways are quite rare.[7,8] Although right-sided Mahaim pathways derive from the initial interventricular ring with node-like property, left-sided Mahaim pathways derive from AV canal myocardium.

Regardless of the location of the Mahaim pathway (right- or left-sided), short AV pathways might have different electrophysiological properties from the other 2 types of Mahaim pathways. Sternick and colleagues[10] reported that short AV pathways had a less node-like property, including adenosine sensitivity and heat-induced automatic rhythm, during RF applications compared with atriofascicular pathways.[10] From this evidence and the difference in the embryological development process between right- and left-sided Mahaim pathways, it is tempting to speculate that left-sided short AV Mahaim pathways have a less AV node–like property than the more common right-sided atriofascicular pathways. In fact, no automatic rhythm was observed during RF applications in the present case. Unfortunately, an adenosine test was not performed. Further studies and additional experience are needed to elucidate the detailed electrophysiological properties of left-sided short AV Mahaim pathways.

Conclusion

We describe a rare case of antidromic AVRT using a left posterolateral Mahaim pathway. The Mahaim pathway was considered to be a short AV pathway connecting the LA to the LV epicardium.

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